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INTERMODULATION MEASUREMENTS IN AUDIO AMPLIFIERS

The evaluation of distortion in audio amplifiers is important in design checking, production testing, and trouble shooting of this equipment. In the quantitative category, two systems have been employed for some time. The first of these makes use of the so-called **distortion meter** or **distortion analyzer** and discovers the total percentage of harmonics with respect to the fundamental test frequency. These instruments operate by removing the fundamental frequency, by means of suitable rejection networks, and measuring with a square law VT voltmeter the r. m. s. voltage then remaining, which is the total harmonic voltage if fundamental suppression has been complete. Because of their manner of operation, such instruments are referred to as harmonic totalizers. The second system employs a **wave analyzer,** which in effect is a selective amplifier tuneable over the audio spectrum. When this instrument is tuned separately to the fundamental test frequency and then to each of its harmonics in the output voltage of an amplifier, the amplitude of each component is indicated directly on the scale of a self-contained VT voltmeter. Under certain conditions, harmonic amplitude measurements by either of the methods just given can show a clean bill of health for an amplifier, while the latter's performance definitely remains unpleasant to the ear.

In recent years, audio engineers have given increased attention to a third method, that of measuring **intermodulation distortion.** Intermodulation between various frequency components in the complex waveforms of speech and music gives rise to disturbing effects in reproduced sound and can escape unnoticed in distortion percentage measurements and frequency runs. Intermodulation may be described as the amplitude modulation of one frequency component by another, usually of a lower frequency by a higher one. It results from non-linearity in some part of the audio system. Audio engineers find that measurements of intermodulation often correlate more closely with listening tests than distortion measurements of other types.

The manner in which intermodulation occurs may be understood by recalling that any non-linear circuit element functions as a modulator when signals of two or more frequencies are presented to it simultaneously. Two interacting frequencies might be two separate fundamentals, a fundamental plus one harmonic, or two harmonics, and so on. Where a number of frequencies are present, as in a complex sound waveform, each may act upon all of the others. The undesired non-linearity might arise from incorrect operating conditions, such as improper bias, in an amplifier stage. A small amount of intermodulation may be of no consequence. However, a disturbing amount of intermodulation can result from harmonic components which separately appear inconsequential in conventional distortion percentage measurements.

Figure 1 illustrates the amplitude modulation process which is instrumental in producing intermodulation in amplifiers. The low-frequency voltage (A) and the high-frequency voltage (B) are applied simultaneously to a non-linear circuit element which delivers an amplitude modulated voltage (C). Here, for purposes of clear illustration, voltages A and B are

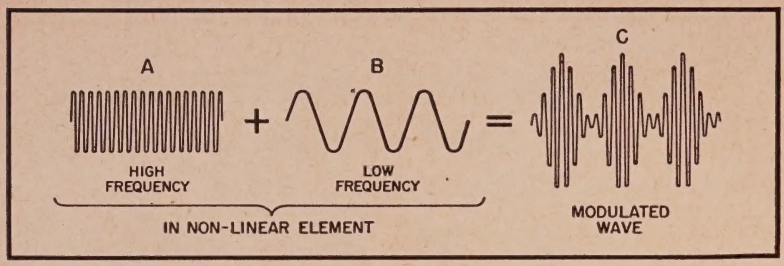

Fig. 1. Waveforms illustrating modulation process.

shown having equal amplitudes. This results in 100% modulation of A by B, as shown in C, an exaggerated condition which hardly would obtain, except under the most extraordinary circumstances, in any practical condition of intermodulation. Note that successive peaks of the modulated wave in C, trace out a modulation envelope which is a replica of the low-frequency modulating voltage wave.

Figure 2 shows the relations in a symmetrical amplitude-modulated waveform. The vertical distance A is the peak amplitude of the unmodulated voltage, while B is the peak amplitude during modulation. The percentage modulation is expressed as 100(B—A)/A. Transmitter technicians will recognize the waveforms of Figures 1 and 2 and the relations shown in Figure 2 as characteristic of amplitude-modulated radio waves. The same sort of modulation takes place in the intermodulation process when voltages of two frequencies encounter non-linearity in an amplifier. In the latter case, the modulation figure is referred to as the **intermodulation percentage.**

The intermodulation percentage may be determined practically by suitably sampling the amplifier output voltage, measuring its A and B peak amplitudes (See Figure 2), and substituting these values in the foregoing equation. This may be accomplished by means of special meter-type instruments or by means of an oscilloscope and suitable filters, as will be shown.

Figure 3 shows modulated waveforms illustrating various degrees of intermodulation. From the equation, numerical relationships will occur to the reader. Thus, for 1% intermodulation the peak modulated amplitude

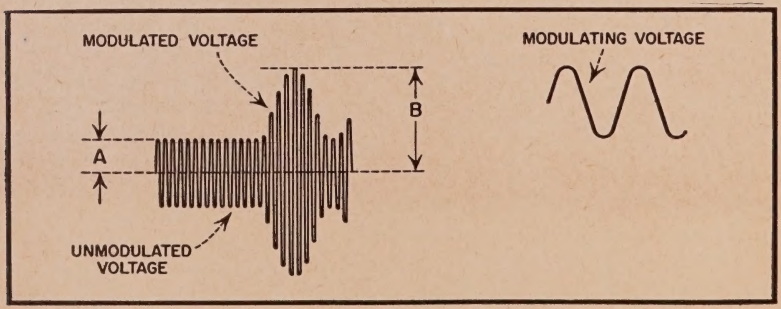

Fig. 2. Relations in amplitude-modulated waveform.

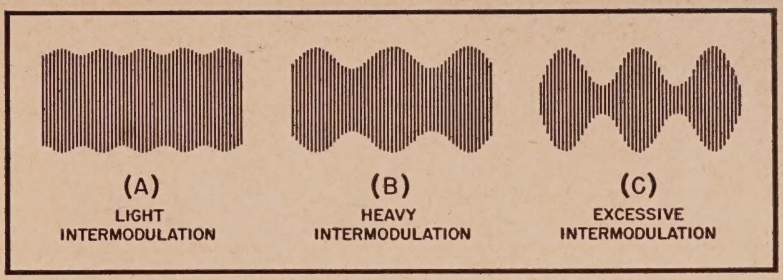

Fig. 3. Comparative degrees of intermodulation.

B (See Figure 2) will be only 1% higher than the unmodulated A. The instrument used to measure this intermodulation percentage must be capable of reading this small increment. If the unmodulated amplitude, for example, is 5 volts, the instrument must show a difference of 0.05 v., or 50 millivolts as the corresponding deflection.

Instruments and Methods for Intermodulation Measurement

In order to check intermodulation in an amplifier, a combined signal, consisting of a low frequency and a high frequency, must be applied simultaneously to the amplifier input terminals. The two signal components can be applied through suitable isolating resistors from separate signal sources, although accepted practice is to mix them ahead of the amplifier in such a manner that a minimum of intermodulation is introduced by the mixing process. In commercial intermodulation meters, this mixing is carried out in a hybrid coil. Mixing also may be accomplished in a suitable tube circuit.

The low frequency usually has some value between 40 and 200 cycles, while the high frequency is between 1000 and 10,000 cycles. Sound servicemen often use 60 cycles as the low-frequency signal component, and 2500 or 3000 cycles as the high frequency. This is convenient, since the 60 cycles can be derived from the power line through a step-down transformer, and the 3000 cycles from an audio oscillator. In this way, only one oscillator is required. However, use of the power-line frequency may give misleading results, especially if hum level is high in some part of the amplifier or measuring equipment. For this reason, a 100-cycle low-frequency component probably is better. In the signal source, some means must be provided for separately adjusting the amplitude of each frequency component.

The amplifier output voltage contains both frequencies with or without intermodulation, depending upon the operating condition of the amplifier. In order to check the amount of intermodulation, the low-frequency component must be removed from the output voltage so that the high-frequency component may be studied for possible intermodulation. This usually is accomplished by means of a high-pass filter, although a band-pass filter also has been used for the purpose.

Figure 4 shows the apparatus setup for checking intermodulation with an oscilloscope. The signal sources may be two audio oscillators of the single-frequency type having negligible distortion. The mixer can be a twin triode or multigrid tube. The high-pass filter may be either inductance-capacitance or resistance-capacitance in type. Waveforms of the signal at various points in the circuit are shown in Figure 4. The oscilloscope is set to give a continuous-train pattern similar to Figure 1(C). Inter-

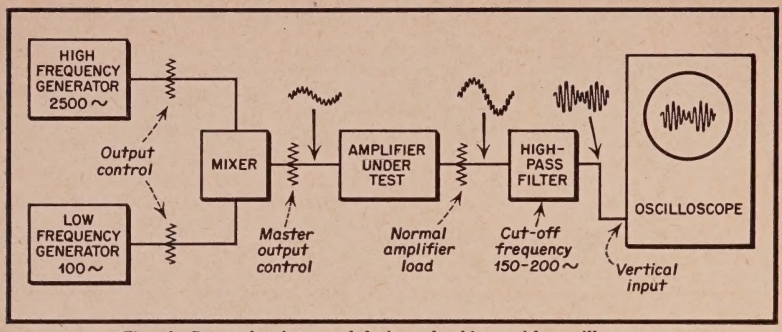

Fig. 4. Setup for intermodulation checking with oscilloscope.

modulation percentage is checked by vertical measurements on the oscilloscope screen, as explained earlier in this article and illustrated in Figure 2.

If the oscilloscope sweep is set to give one complete cycle of the high-frequency component, a somewhat different measurement procedure may be employed: The thickness of the trace at both the positive and negative peaks may be measured, the two thicknesses added, and the sum compared with the distance measured from positive peak to negative peak. This is illustrated in Figure 5. A and B are the thicknesses of positive and negative peaks, respectively, while C is the peak-to-peak height. Intermodulation percentage in this case is equal to $100(A + B)/C$. In order for this method to be accurate, the high-pass filter must be efficient and the oscilloscope must be free from hum pickup and defocusing effects. This method has the further advantage that any departures from sine waveform, due to harmonic distortion, can be detected in addition to modulation effects.

Figure 6 shows a simple resistance-capacitance type high-pass filter suitable for separating the high-frequency from the low-frequency component.

Aside from oscilloscope measurements of intermodulation, direct-reading intermodulation meters frequently are used for percentage indications. These latter instruments utilize a straightforward arrangement.

Figure 7 shows the block diagram of a typical intermodulation meter which may be set up from standard components by the audio experimenter. Transmitter technicians will recognize this layout as being identical with the percent modulation meters employed to check a. m. transmitters. The waveform of the signal at various stages in the instrument is shown in Figure 7.

The intermodulation meter operates in the following manner: The output signal from the amplifier under test contains both the low and high-frequency test signals superimposed as shown by waveform 1. The high-pass filter (A) removes the low-frequency component and transmits only the modulated high-frequency component shown

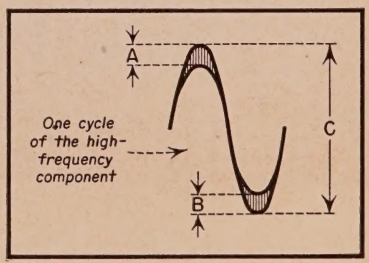

Fig. 5. Single-cycle waveform for percentage measurement.

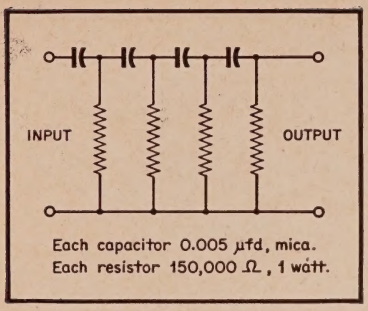

Fig. 6. R-C high-pass filter for I.M. measurements.

by waveform 2. An amplifier (B) having negligible distortion, amplifies this modulated wave (See waveform 3) which then is applied to a linear demodulator (C) such as a shunt-diode rectifier. A d. c. milliammeter (D) actuated by the rectified current of the demodulator permits the test-signal level always to be set to a predetermined reference value (say, half-scale of the meter). The deflection of this meter is proportional to the average carrier (high-frequency component). The output of the demodulator has waveform 4. A low-pass filter (E) removes the high-frequency component from the demodulator output and transmits only the low-frequency modulation envelope (waveform 5) to the a. c. vacuum-tube voltmeter (F). The scale of the latter is graduated directly in modulation percentage. Intermodulation percentage, as read by means of the VT voltmeter, is correct when the test signal level is adjusted for reference deflection of meter D.

In commercial intermodulation meters, there often are many variations of the scheme illustrated in Figure 7. For example, more than one amplifier stage may be employed. In some factory-built instruments, an amplifier is placed before and after each filter. However, the operating principle is the same.

Evaluation of Intermodulation

There are at present no set standards with reference to intermodulation percentage and its correlation with overall amplifier performance. While there is general agreement that intermodulation tests are more sensitive than harmonic distortion measurements in revealing the presence of certain types of distortion, the percentage of intermodulation considered tolerable by one manufacturer is apt to differ from the standards of another manufacturer.

Intermodulation measurements are of particular interest in film and disc recording. However, it is not recommended that they replace other methods of distortion measurement entirely, but rather that they supplement these other methods.

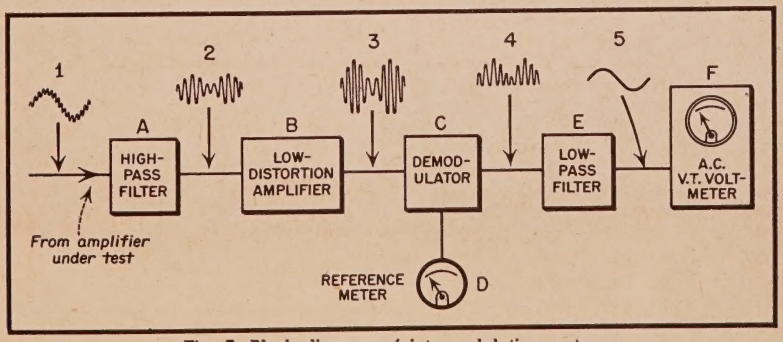

Fig. 7. Block diagram of intermodulation meter.

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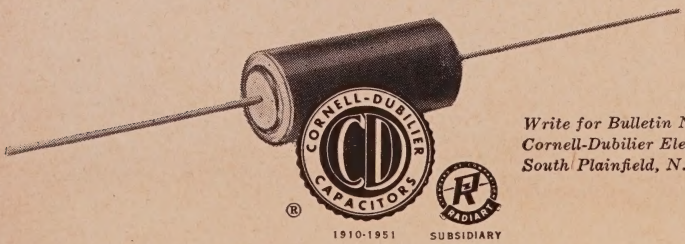

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WANTED—NC 57 or S-40A. Also need Riders Manuals 9—15 and up. Will pay cash. G. H. Swiska, 109 E. School St., Woonsocket, R. I.

WANTED—4 or 5 BC-645-A transceivers or surplus radar equipment, particularly scopes. Will consider other VHF and UHF equip. Have 1/4" scale model RR equip. worth $175. Stamp for list. Robert C. Morrison, 13 Sever St., Plymouth, Mass.

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FOR SALE—Amplifier (custom made) complete with an equalizer and pre amp. Uses a 6AS7G output tube, cathode follower circuit. William T. Raymond, Madigan Hospital, Ward 25A, Tacoma 9, Wash.

FOR SALE—Four-Way Arc Welder, 110V a.c. or d.c., simplified instructions, complete with goggles and rods, $8. R. L. Armstrong, 6041 S. Prairie, Chicago 37, Illinois.

SALE OR TRADE—Heathkit VTVM and sig. gen; NRI sig. tracer and VOM (batttery operated); Sunbeam Shavemaster electric razor; Sprayberry radio course complete with experiments. Best offer takes all or part. E. Kostelnak, 5033 So. Seeley Ave., Chicago 9, Ill.

SELL OR TRADE—Have Xmitting equip., Sonar XE10, Xtal mic., Vibroplex bug, tubes. Want communications course, CREI sections 1 and 2, or similar course. J. Pyryt, 140 Hamilton Ave., Lodi, N. J.

SWAP—Supreme No. 385 automatic tube and set tester; Radiotechnic tube tester, counter model; and NRI vacuum tube voltmeter. Want good BC-348Q receiver. John Herman, 803 W. Locust St., Bloomington, Illinois.

WANTED—Circuit diagram of amplifier using 4 2A3's, 2 56's, and 2 57's. Transformer coupled — 80 power supply. A. J. Catalano, 713 William St., Omaha 8, Nebr.

FOR SALE—10 watt xmtr with pwr supply, tubes, $8; 4 tube audio amplifier, spkr, $10; turntable, 78 r.p.m. motor, crystal pickup, $5. M. Konon, 244 Irving Ave., Brooklyn 27, N. Y.

WANTED—NC-57 or S-40. Will trade tubes or pay cash. State price wanted. G. H. Swiska, 109 E. School St., Woonsocket, R. I.

SWAP—G.E. intercom system, master and 4 subs, perfect, for good vacuum tube VOM. Also ¼ h.p. motor for ? and 1938 Packard Sedan (good) for good TV. William J. Molaney, 26 Lilly Ave., Brockton 25, Mass.

FOR SALE—Snaider Auditorium 20 x 26 projection TV set. 37 tubes, Dumont Inputuner, Bausch & Lomb f1.9 lens, Eastman Kodak rear projection screen, 12 watt hi-fi audio, etc. List $1,495.00, sacrifice at $598. Excellent cond. Details. N. P. Forcier, Essex St., Middleton, Mass.

WANTED—Vol. 1 to present date Riders Manuals, cash waits best offer; test equip.; good 6V d.c. - 110V a.c. mobile sound system. Radio Red, 420 Main, Texarkana, Texas.

WANTED—Hammarlund Super Pro, about 1938 model with broadcast separate power supply, any condition. Garry Ellerman, 156 Highland, Cambridge, Ohio.

FOR SALE—Simpson Genescope model 480, used only three months. New Price $395, sacrifice $320. Herman C. Hall, Halls Mills, N. C.

FOR SALE—1941 International "Metro" ¾ ton truck. 1947 motor, heater, new paint, good tires. Equipped as rolling repair shop for radio, TV, or appliances. Extension ladder included. Make offer. Lester Porter, 220 E. Poplar St., Danville, Indiana.

FOR SALE—16mm sound camera housing, film magazine, optics, etc. Patterns for 400' film magazine and 16" turntable. Western Electric dynamic mike, WE electric eye equipment, Meissner FM tuner, WE crystals. Earl Cox, 3625 Euclid Ave., Berwyn, Illinois.

FOR SALE—Motorola deluxe custom push-button radios for 1942-1951 Buicks, Olds, Pontiac, Chev., Hudson, etc. Only $55.20 while they last. Simon L. Cherry, 1436-38 Belfield Ave., Philadelphia 40, Pa.

WANTED TO BUY—Ham transmitter and receiver. State full description and price in first letter. Nathan W. Anderson, 1114 Idaho St., Norman, Oklahoma.

FOR SALE OR TRADE—Best offer takes vol. 6 thru 14 Riders. Consider camera equipment. D. M. Raw, Clearwater, Minn.

FOR SALE—FM Pilotuner, like new, $17 postpaid. Warren Thomas, 10 E. 12th St., Tyrone, Pa.

FOR SALE—Hallicrafters HT-6 transmitter, excellent condition, complete with tubes, coils for all bands, Astatic W-30 mike, ECO units for 20, 40, 75, and 160 meters, original operating instructions. Best offer over $100. Dale W. Rockwell, Arlington, Nebr.

FOR SALE—G.E. TC-3A tube and battery tester, complete with latest tube test data. Also model 201 Crystaliner sig. gen. with 2 extra crystals and instructions. Will sell separately, best offer. George V. Hanold, Box 133, Wonewoc, Wis.

FOR SALE—Hickok sig. gen., model OS-10, freq. range 85kc. to 50mg., in perfect working cond., $35 f.o.b. Also Triplett model 666H pocket VOM, $10 f.o.b. Ray Appelhans, Pen Mar, Pa.

WANTED—For cash. Setchell Carlson model DM1 Dor-A-Fone units. Also DS10 switches and other allied equip. Can be reasonably inoperative. State price and details. Kenneth Byers, 1422 N. Glendale, Peoria 3, Illinois.

SELL OR TRADE—Zenith Trans-oceanic portable; McMurdo Silver 1VA Masterpiece all-wave receiver; National NC-44 communication type receiver. All in good condition. Want Hammarlund Super Pro, TV rec., or what? Glenn Watt, 415 W. First St., Chanute, Kansas.

FOR SALE OR TRADE—Supreme set tester model 504-A, and a Foley saw filer model 16. Both are like new, never used. What have you? Dale E. Sigler, RFD 4, Bedford, Pa.

FOR SALE—BC-348-R well converted, built on Hallicrafters speaker, noise limiter, etc., $135; Mark II complete, $40; National HFS, excellent, $150; transformers, meters, etc. Roland Bond, 2637 Westminister Ave., Dallas 5, Texas.

WANTED—Heterodyne or absorption frequency or wave meter or grid dipper, carbon or crystal mike. Have many ham items to swap or will pay cash. O. T. Neau, 120 Afton Pkwy., Portsmouth, Va.

POSITION WANTED—In New York City area. 18 year old high school grad experienced in TV repair, now part time self employed — good references. Robert Wexelbaum, 1154 Stratford Ave., Bronx 59, N. Y.

FOR SALE—12 tube British 5 band rec., 60kc. to 30mc., a.c. or d.c., needs some work; two Precision E-200 sig. gens., shelf worn; ARB Navy aircraft rec., 195 kc. to 9.5mc., converted to a.c. Make offer. Radio & Electronics, 508 Lincoln, Waukesha, Wisconsin.

FOR SALE—RCA record changer, magnetic pick-up, 12 years old, heavy duty motor, excellent condition. Best offer. Also heavy duty power supply, 150V regulated and 2300V, army surplus. G & M Service, 772 So. 19th St., Newark 3, N. J.

FOR SALE—Model 599, ser. No. 7333, Supreme tube and set tester, needs repairs, first $18.50 gets it; limited supply Hoffman 5 tube table radios, $20; 3" reflector Justrite carbide lamps, $2.. Postpaid, no c.o.d. Bender Supply, Sealy, Texas.

FOR SALE—Rider Manuals, No. 6 through 17 inclusive. All twelve books in perfect condition, $96 c.o.d., or any number at $8 ea. Home Radio & Electric Shop, 1799 Post Road, Fairfield, Conn.

SWAP—Exchange wanted for an excellent Hallicrafter S-38B an equally priced first class FM/AM receiver. E. Mueller, 29 Howard St., New Britian, Conn.

WANTED—Will buy any volumes of Sam's Photofacts. Must be in good condition. Write giving price. William P. Amos, 2004 Joyce Ave., Columbus 11, Ohio.

FOR SALE—Heathkit scope, model O-6, $39.50; Heathkit signal gen., model SG-6, $19.50. Both completely wired, 2 mos. old, work fine. Want ART-13. A. Brocato, 1217 N. 33rd St., Birmingham, Ala.

FOR SALE—Vibroplex "Bug," and Bud code practice audio oscillator. Also gooseneck fluorescent desk lamp, including fluorescent bulb. All in excellent condition. Stanley J. Rubel, 1872 Monroe Ave., New York 57, N. Y.

SALE OR TRADE—16mm movie camera and projector, plus sound head to convert to sound, set of movie and studio lights, Federal disc recorder, electronic flash gun, 2 phono motors, Newcomb power supply, small bench drill with motor. Samuel Harelick, 27 East 39th St., Bayonne, New Jersey.

WANTED—Xtal controlled phone xmitter to cover 146 mc. and lower frequencies, communications receiver, 2 meter converter or preselector. Will buy or swap for 8mm or 16mm movie equip. Have many types. E. Lewy, 853 N. Eutaw St., Baltimore 1, Md.

FOR SALE OR TRADE—Scott Philharmonic 30 tube console, volume expander and scratch suppresser, factory checked, $195; Contax 1A, 11 with flash built in and Rolleicord 1A, all first class. Consider trade for AM-FM tuner and/or high grade amplifier. J. Cooper, 445 E. Grand Blvd., Detroit 7, Mich.

FOR SALE—906 McMurdo sig. gen. AM-FM, used very little; Model TS-2 Feiler sig. tracer. Best Offer. Also several 16mm sound projectors rebuilt and guaranteed. Several reels 400' sound films. Ship anywhere. Lewis M. Stone, 1409 Ford Ave., Tarrant City 7, Alabama.

FOR SALE—Model 80 Webster Wire Recorder, $75; Natco 16mm sound projector, $150. Both in good condition. Kenneth F. Burton Radio TV Lab, 2519 Second Ave., Richmond 22, Va.

WANTED—CREI News: Jan., Mar., 1946; Aug., Oct., 1947; Jan, Feb., 1948. Naval Reservist: Mar., Apr., 1949. Instruction Book: Howard Receiver Model 430 Series 3. Name price. Have HRO & IM Series Instruction Books. James Nichols, 1907 8th St., Marysville, Washington.

WANTED — Modulation transformer, 300 watt multi-match type. Quote price. R. E. Schlosser, 503 Fifth St., Defiance, Ohio.

WANTED—Car radio and mounting instructions, to fit 1941 Plymouth. Must be in good condition. Alan York, 1342 40 St., Brooklyn 18, N. Y.

WANTED—8BP4 TV tube. Have radio parts, tubes, and "ham" components to trade. H. F. Bernard, 3670 S.W. 9th Ter., Miami, Fla.

FOR SALE—Pocket VOM Triplett, model 666-H. Tests up to 5000 volts a.c. or d.c. Perfect condition, price only $15. Leon Medler, 2109 Daly Ave., Bronx 60, N. Y.

FOR SALE OR TRADE—Zenith Neon Skeletain Sign with transformer, used 2 hrs. Trade for Triplett pocket type multimeter or sell for cash. F. Lovett, P.O. Box 143, Newland, N. C.

WANTED—New or used 5TP4 projection tube. Tony Slapkowski, Box 439, Sicklerville, N. J.

FOR SALE—5" TV kit, 20 tubes, 1 picture tube and 19 tubes included. No cabinet, very good, $45. B. H. Buchanan, Hawk, N. C.

SALE OR TRADE—Army model Colt 45, good condition, new barrel, $25 f.o.b. Will accept new, cartoned, late code TV tubes of standard brands, equal net value. Ellis Radio Service, Vermilion, Ohio.

FOR SALE—Precision Model E-200 signal gen., $40; Precision Model 10-12-P tube and battery tester, $65; Riders vols. 8 thru 17 incl., with indexes, $100. All items in A-1 condition. S. R. Kangas, P.O. Box 14, Hurley, Wisc.

SWAP OR SELL—Weston model 772 multimeter, 20,000 ohm/volt, perfect, portable wood case and cover. Want Eico model 425K scope, Eico model 625K tube tester, or Eico model 315 sig. gen. A. V. Bragg, Douglasville, Ga.

TRADE OR SELL—Precision EV-10P VTVM and E-200C sig. gen., radio and engineering books, transformers, chokes, tubes, Skilsaw. Want plate camera, bandsaw, grinder, lathe, cordwood saw, 5-10 h.p. gasoline motor, welding equip. C. M. Bend, R. 4, Stillwater, Minn.

FOR SALE—Used table, midget, and portable sets complete with cabinets. Some in playing condition while others need repairs. Alvin Kriegel, 701 Crotona Pk. North, Bronx 57, N. Y.

TRADE—7" TV set in mahogany cabinet with one booster and working, in good shape. Want good tube tester or scope or generator. John Arnold, P.O. Box 84, Bluffs, Ill.

WANTED—A. E. Harper's book Rhombic Antenna Design, published in 1941. John Fill 1407 College Avenue, Hartsville, S. C.

WANTED—Sams Photo-facts numbers 51 to 68 incl., 103 and up. Elmer E. Ash, 431 N. Milwaukee St., Port Washington, Wisc.

SELL—Mark II xmitr. perfect, unconverted with 12V dynamotor supply, shock mounts, mike phones, ant tuner, canvas cover, vertical ant and mount, $35. An 832, $4.50; 832A, $8.50. G. F. Gnandt, RFD 2, Wellington, Ohio.

SELL OR SWAP—7EP4 TV tube, excellent, $15; 2 Webster 78 r.p.m. changers, $15 ea. Want SCR-522 transmitter, ARC-4 or 2 meter equip., BC-1284 amplyf. George W. Harrold, 1907 So. Park Ave., Haddon Heights, N. J.

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